A Literature-Based Exploration of Servitization in Engineer-to-Order Companies

Antonio Masi(✉), Margherita Pero, and Nizar Abdelkafi

Politecnico Di Milano, Milano, Italy
antonio.masi@polimi.it

Abstract. Servitization allows manufacturing companies to enrich their value proposition with services. It enables them to differentiate their offers from competitors, while capitalizing more on digital technologies. Servitization practices such as maintenance services, training and advisory, or rental and leasing solutions are widespread among many sectors. In this paper, we focus on the ETO context. We explore the literature to capture how and why servitization has been adopted by ETO companies. Based on our findings, we build a theoretical framework that we partly validate through an analysis of secondary sources. We conclude the paper with possible future research directions.

Keywords: Engineer to Order · Servitization · Product-Service Systems

1 Introduction

For many companies, digitalization is a strategic pillar of the future. It is expected to reshape manufacturing and drive the Fourth Industrial Revolution, also referred to as "Industry 4.0" [1]. Digital technologies are enablers of servitization [2], the process by which industrial companies change their offers from mere products to bundles of products and services, or Product-Service Systems (PSS) [3].

A recent survey that investigates European capital goods manufacturers' transition towards service-oriented business models [4] shows that services are widely adopted by European manufacturers and generate, on average, about 20% of their sales. Nevertheless, PSS is rather limited to product-related services such as repair and spare parts provision. The same study, however, found that most respondents expect that servitisation will become more important in the future, and that there is a lot of unexploited potential for the adoption of digital technologies, especially in small enterprises.

There is a large body of research on servitization, but this paper addresses a particular context, in which servitization can take place: the Engineer-to-Order (ETO) context. In ETO, companies carry out engineering activities according to specific customer requests. Most literature treats engineering in the ETO context as one single compact activity. According to Cannas et al. [5], however, engineering – at the physical product level – consists of many sub-activities: research, develop, design, modify (major changes), modify (minor changes), and combine. Thus, it is possible to define different types of

Published by Springer Nature Switzerland AG 2021
A. Dolgui et al. (Eds.): APMS 2021, IFIP AICT 633, pp. 354–362, 2021.
https://doi.org/10.1007/978-3-030-85910-7_37

ETO-companies, depending on the sub-activity, at which the customer order enters. Cannas et al. [5] also mention that ETO companies have been traditionally more focused on complex and highly customized products than on servitization. By analogy to products, and by extending engineering sub-activities to services, ETO companies may combine product and service engineering activities to better fit customers' requirements. Conceptually, ETO companies can leverage standardized services or specifically engineered services to enrich their ETO products. Digitalization even increases the possibility that such ETO companies will be more widespread in the future.

To the best of our knowledge, the simultaneous consideration of product and service engineering has not been addressed explicitly. This paper starts by exploring current literature related to how ETO companies adapt to embrace smart PSS. It aims to initiate a discussion on the implications of servitization in ETO companies by dealing with the research question (RQ): "*Why do ETO companies apply servitization? And how?*". To answer this question, we look for literature review and draw on secondary online sources.

2 Methodology

To get a general overview of the topic, the first phase of this research was exploratory, based on a non-systematic scouting of both sources from peer-reviewed journals and from company websites. In particular, we analyzed in detail the website of Biesse S.p.A. (www.biesse.com), since it is the largest machinery producer in Italy by revenue in 2019 – according to the informatic analysis of Italian companies (https://aida.bvdinfo.com/version-2021727/home.serv?product=AidaNeo) – and machinery is a key ETO industry [e.g., 5–7].

Then, we searched relevant articles in the Scopus database. We tried different keywords and refined our query by trial and error. The starting keywords for ETO were derived from the literature review by Gosling and Naim [7], since it is the most cited systematic literature review on this subject. Choosing the keywords related to servitisation was harder, due to the "blurred" [8, p. 261] boundaries between the terms related to it. Eventually, the starting keywords for servitisation were based on those used by Paschou et al. [9] for two main reasons. First, it is one of the most recent literature reviews on the topic. Second, it is based on the keywords used by Baines et al. [3] who, in turn, published the most highly cited review on this subject, and the second most cited article (1188) when searching for "serviti*ation" on Scopus. So, these keywords seemed the best starting point for the literature search.

After several attempts, we refined our starting query into the following search string: (TITLE ABS KEY ("serviti*ation" OR "product service system" OR "inte-grated solution*" OR "service transformation" OR "service infusion" OR "service focused" OR "industrial service") AND TITLE ABS KEY ("engineer to order" OR "design to order" OR "one of a kind" OR "project based")) AND (LIMIT TO (LANGUAGE, "English")).

A possible limitation of this query is the string "project based". This string was the result of refining the keyword "project", which was used by Gosling and Naim [7] but that was leading to too many results to be screened. Actually, by modifying it into "project-based" it was possible to include papers related to "project based organizations" or "project based firms". Although this string led to some irrelevant papers in later stages,

its omission would have possibly resulted in neglecting relevant contributions, which is why we included it.

Our string led us to 41 articles we later filtered as follows. First, we screened title, abstract and keywords of the papers, excluding: 8 duplicates, which were collections of conference articles that were also present separately; 4 articles related to "project based learning"; 4 articles related to energy engineering; and, finally, other 11 papers not related to servitisation. For instance, a paper was discussing project-based organizations deeply, but unrelated to servitisation [10]. So, out of 41 papers, only 14 passed this first step.

Second, we went through the full text of the articles to select only those related to ETO contexts. This step was necessary especially for "project based" papers, since this is a subset larger than ETO, as Moretto [11, p. 4] pointed out: "among the possible project-based organizations, we chose engineer-to-order (ETO) companies as the unit of analysis of the study". In this step, more precisely, we were looking for statements in the articles to show that the contexts analyzed by the authors are companies making products that are engineered to order. Here are examples of quotes from the selected articles: "the five solutions that we included in the analysis all have an engineer, procure, construct (EPC)—project delivery followed by long-term O&M [Operations and Maintenance] service contract" [12, p. 963]; "EngCo (a pseudonym) is an original equipment manufacturer which develops, produces and manages engineering products, including through-life support" [13, p. 255]. This step resulted in 9 papers.

Finally, we analyzed the selected papers. In line with the methodological guidelines provided by Grant et al. [14], we firstly characterized the selected papers according to demographics (year of publication, source ranking, citations), methodologies employed and contexts discussed. This was done to identify the least commonly discussed methods and contexts, which would deserve further attention by future research. Then, we dived deeper into the content of the selected papers, looking for answers to our RQ. In particular, with respect to our 'why' RQ, we decided to frame the insights collected from the papers within the Strength, Weaknesses, Opportunities and Threats (SWOT) framework [15]. This framework allowed us to organize the reasons favoring servitisation in four categories, related to internal (Strengths and Weaknesses) and external (Opportunities and Threats) environments, in which firms operate. It is chosen for its clarity and completeness. Moreover, it is widely used by practitioners [15], who may be interested in our study.

3 Results

3.1 Bibliometric Analysis

Demographic Analysis. The final set consists of seven journal articles and two conference papers. Most journal articles (4 papers) were published in the International Journal of Project Management. This can be explained by the project-based nature of ETO manufacturing. All articles were published between 2008 and 2019 without noteworthy peaks. All the sources of the selected articles are placed in the first quartile (Q1) of the Scimago Journal Rank (SJR), except for one, which is classified Q2. Thus, according to SJR, the selected articles have a medium to high quality, which is a good indicator for the reliability of the published results. In addition, the selected articles have, on average,

about 25 citations, with 6 papers having more than 10 citations and one [16] with 92 citations. This suggests that the articles in our sample had a relatively good impact on the research community.

Methodology Analysis. All selected articles used a case study methodology. Most of them (six papers) develop single case studies. In three articles, the re-searchers use multiple case study analysis. Most of the papers of our sample recognized the low generalizability of the results they obtained [e.g., 12, 13, 17, 18].

Context Analysis. The companies analyzed in the case studies belong to two main sectors: machinery and construction (Table 1). These sectors are different regarding the size of the product. Machines are smaller than buildings and can be produced off-site, while construction projects produce larger facilities that are built on-site. Construction and machinery are typical industries in the ETO literature [7].

Examples of machinery from the reviewed papers are: computerized numerical controlled machine centers [19]; energy systems [18]; mold-making machines [17]; material handling equipment [21]. Within the construction industry companies deliver products such as power plants [12, 16]; sludge treatment centers [21], and telecom networks [22].

Only two papers develop case studies in both industries: machinery and construction [21, 22], whereas seven papers focus on only one industry. Note, however, that other typical ETO sectors such as shipbuilding [23] and aerospace [6] are not present in our final sample.

Table 1. Characteristics of the case studies reviewed

Reference	Case Study	Machinery	Construction
[19]	Multiple	9	0
[16]	Single	0	1
[18]	Single	1	0
[12]	Single	0	1
[22]	Multiple	4	1
[17]	Single	1	0
[20]	Single	1	0
[13]	Single	1	0
[21]	Multiple	2	1
	TOTAL	19	4

3.2 Content Analysis

How Do ETO Companies Apply Servitization? The papers selected for our re-view describe servitization in ETO companies from different perspectives: an opportunity for

certain companies to leverage on new technologies to improve specific services [17, 20], a trend that is involving entire sectors, which are offering more and more complex bundles of products and services [13, 18, 19, 21], or a new business model [12, 16, 22]. More specifically, Kujala [12, 16] notice that, due to the project-based nature of capital goods products, a servitization business model in an ETO context should be seen as "solution specific".

To classify companies, authors use two main taxonomies for servitization: one is focused on product lifecycle, and the other on the characteristics of the services.

Artto et al. [22] use a product lifecycle taxonomy. They distinguish servitization practices implemented before, during, and after project delivery. Because the authors understand engineering as a service, all ETO companies adopt "by definition" at least one servitization practice.

Kujala et al. [12, 16] and Raja et al. [13] use a taxonomy related to the characteristics of service. Based on previous literature, they distinguish between product-oriented offerings, use-oriented offerings, and result-oriented offerings. These categories lead to different types of services and different types of buyer-supplier relationships [16]. For instance, for product-oriented offerings arms-length relationships are enough, while result-oriented offerings require integration of focal firm, buyers, and suppliers.

Supply chain integration and coordination have been discussed not only in Kujala et al. [12, 16], but also in other studies. ETO companies that want to embrace servitization should dramatically improve their inter-firm and intra-firm coordination. For instance, Ivory and Alderman [21] stress the problems of downstream coordination for ETO companies offering PSS, especially because they often have to interact with several stakeholders along a project lifecycle.

Why Should an ETO Company Pursue Servitization? ETO companies adopt servitization for many reasons. We organize the motives for servitization according to the Strengths, Weaknesses, Opportunities, and Threats (SWOT) framework [15].

ETO companies face two external threats: general economic downturn, which can cause demand stagnation, especially in Europe [13, 16] and increasing globalization, which allows manufacturers from low-cost countries to compete with well-established ETO companies by offering lower prices [13, 16, 19]. Servitization can enable companies to deal better with the decreasing domestic demand and increasing competition from overseas suppliers.

To address these threats ETO firms can either cut costs and shift towards mass-customization or become more effective through differentiation [24]. This differentiation can be achieved by offering value-adding services to satisfy the needs of the customers better. In addition, customers of capital-intensive systems have become increasingly interested in the life-cycle costs of their investments [12]. ETO products typically have long lifecycles, high total costs of ownership, and expensive downtimes [19]. Thus, services such as after-sales support, training, advisory, spare parts provision, and maintenance are highly attractive to clients that are aware of the total cost of ownership [21].

Servitization can support ETO companies to achieve two (inter-related) opportunities: digitalization and sustainability. Technologies such as Artificial Intelligence [17]

and Augmented Reality [20] can trigger new or improved services, e.g., predictive maintenance. Servitization can also lead to the production of fewer, but highly value-adding products, thus consuming fewer resources, in line with the "dematerialized solution" paradigm [20, p. 219].

Servitization allows ETO firms to capitalize on a major strength, which is their assets base located in the customers' facilities. The more products ETO companies deliver to their customers, the more services they can sell, an effect that is amplified by the typical long lifecycle of ETO products [13, 16]. The availability of these assets can reduce the impact of a major structural weakness of ETO companies: the "lumpy" demand. "Service revenues from an installed asset base can provide a buffer against fluctuating demand cycles" [13, p. 250].

4 Discussion

The 9 papers reviewed discuss 23 cases of servitisation in ETO and capture different reasons for embarking on it. This answers our 'why' research question. Understanding 'how' ETO companies apply servitisation was more difficult, since there was less information about concerning this aspect on the sources we reviewed. Nonetheless, we found some interesting insights, in particular in Kujala et al. [16].

Kujala et al. [16] describe two types of PSS in ETO contexts. The first is represented by project-led solutions, where an Operations & Maintenance (O&M) contract is offered independently of the product, and the contract is almost standard. The second is represented by life-cycle-led solutions, that are "seamless offering for the customer, consisting of an integrated EPC project and O&M service" [16, p. 101]. The authors also observed that the life-cycle-led solution was more profitable than the project-led one. The distinction made by these scholars highlighted two different levels of service customization in ETO companies offering PSS: PSS with a standardized service component, and PSS with a service highly customized and strictly connected to the product.

This dichotomy between high and low levels of standardized services in PSS should be particularly interesting for ETO companies, since we know from recent developments in the literature [e.g., 5, 6] that within the context of ETO there are different levels of product customization, too. In fact, many ETO companies are pursuing mass customization, by offering less tailor-made products, but still answering to customer orders', thanks to levers such as modularity and technology [6].

Therefore, we elaborated especially on the results in [16] and [5] to propose a theoretical framework that combine the product and service customization levels dimensions (Fig. 1). On the x-axis, we represent the product customization dimension, which can range from low to high (of course, always in the range of ETO products). On the y-axis, we represent the service customization dimension, which also ranges from low to high.

Within this matrix, it is possible to position the two configurations mentioned by Kujala et al. [16], whose article discusses PSS composed by services with different levels of customization and with EPC products. However, it is also possible to position other product families with lower level of product customization as the one of the PSS discussed by the aforementioned work. In this sense, Biesse is an interesting case, which

we previously mentioned above. Biesse (www.biesse.com) is a world-leader producer of wood working machines. It claims, in the brochure of one of its products, the ROVER-A16, that "a team of specialized sales engineers can understand production requirements and suggest the optimal machine configuration." This means that this product is likely to be "standard customized", in line with the definition provided in [5]. In addition, Biesse also offers several services, as shown by its 3-years business plan. In particular, their installation and maintenance services are more standardized than the ones described in [16]. Therefore, this case is placed in the bottom left corner of our matrix.

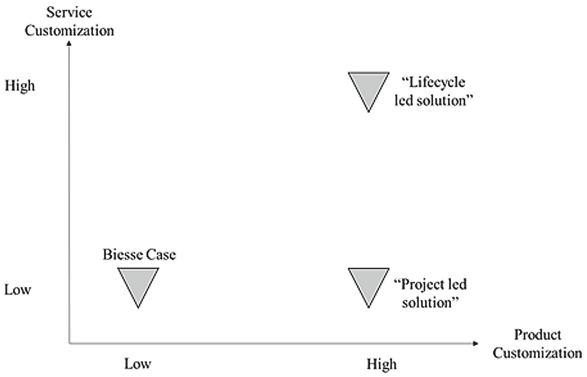

Fig. 1. ETO product-service strategic matrix

The matrix shows that companies can develop different approaches for the integration of products and services, ranging from standardized products and services, that can be designed independently of the customer, to customized products and services that are designed together with the customer. In line with Kujala et al. [16], we believe that the different positions on the matrix can have an im-pact on the level of profitability of ETO companies. For this reason, we propose that this matrix can be used as a strategic tool to map the different options in terms of PSS variety when ETO companies adopt servitisation.

Additionally, we expect that the different quadrants in the matrix have deep implications for operational activities. For instance, when product and service customization are high, higher inter-functional coordination as well as adaptations of the sales, design and delivery processes are required. To be able to confirm this proposition, however, future research is needed.

5 Conclusions

This paper proposes a literature-based exploration of servitization in ETO companies, by investigating why and how ETO companies embrace it. To this aim, based on the results of a systematic literature review and case studies from secondary sources, a SWOT analysis and a strategic matrix have been built. The results suggest that servitization can be a strategic lever, which enables ETO companies to differentiate themselves from

other companies, in face of the downsizing of domestic demand and the increasing competition from overseas companies. Servitization allows ETO companies to leverage the opportunity of having the company's asset base located at the customer's site, and coupled with digitalization, to propose sustainable solutions. For ETO companies, thanks to servitization, differentiation can now occur along two axes, i.e., the product and the service.

From a managerial perspective, this paper provides a strategic matrix, which can be used by companies to define their positioning in terms of product and service customization, while comparing their positioning with their competitors. Moreover, the SWOT analysis may clarify to managers in ETO companies the possible reasons to adopt servitisation.

The main theoretical contribution of this paper is to highlight the need to better explore servitization in ETO. Some future research directions emerge from the results of this paper. First, the proposed matrix should be improved and detailed, e.g., with metrics to assess the positioning along the axes. Indeed, one limitation of this study is the limited number of cases and papers included. Therefore, future research can be devoted to enrich the set of cases within the matrix. Then, how to put in practice the different strategies identified with the proposed matrix should be investigated, e.g., in terms of the positioning of the Customer Order Decoupling Point (CODP), software and technologies supporting each strategy, and upstream and downstream coordination along the supply chain. In addition, it is important to diversify the sectors and expand the analysis to cross-sectoral studies, especially to include industries – like shipbuilding and aerospace – which have not been discussed as much in the extant literature. Finally, as we pointed out in the demographic analysis, the articles we reviewed use only the case study methodology, the application of other methodologies can help to refine the results discussed in the reviewed articles.

References

1. Xu, L.D., Xu, E.L., Li, L.: Industry 4.0: state of the art and future trends. Int. J. Prod. Res. **56**(8), 2941–2962 (2018). https://doi.org/10.1080/00207543.2018.1444806
2. Pirola, F., Boucher, X., Wiesner, S., Pezzotta, G.: Digital technologies in product-service systems: a literature review and a research agenda. Comput. Ind. **123**, 103301 (2020). https://doi.org/10.1016/j.compind.2020.103301
3. Baines, T.S., et al.: State-of-the-art in product-service systems. Proc. Inst. Mech. Eng. Part B: J. Eng. Manufact. **221**(10), 1543–1552 (2007). https://doi.org/10.1243/09544054JEM858
4. Adrodegari, F., Bacchetti, A., Saccani, N., Arnaiz, A., Meiren, T.: The transition towards service-oriented business models: a European survey on capital goods manufacturers. Int. J. Eng. Bus. Manage. **10**, 1–10 (2018). https://doi.org/10.1177/1847979018754469
5. Cannas, V.G., Gosling, J., Pero, M., Rossi, T.: Engineering and production decoupling configurations: an empirical study in the machinery industry. Int. J. Prod. Econ. **216**, 173–189 (2019). https://doi.org/10.1016/j.ijpe.2019.04.025
6. Cannas, V.G., Masi, A., Pero, M., Brunø, T.D.: Implementing configurators to enable mass customization in the Engineer-to-Order industry: a multiple case study research. Prod. Plann. Control, 1–21 (2020). https://doi.org/10.1080/09537287.2020.1837941
7. Gosling, J., Naim, M.M.: Engineer-to-order supply chain management: a literature review and research agenda. Int. J. Prod. Econ. **122**(2), 741–754 (2009). https://doi.org/10.1016/j.ijpe.2009.07.002

8. Baines, T., Ziaee Bigdeli, A., Bustinza, O.F., Shi, V.G., Baldwin, J., Ridgway, K.: Servitization: revisiting the state-of-the-art and research priorities. Int. J. Oper. Prod. Manage. **37**(2), 256–278 (2017). https://doi.org/10.1108/IJOPM-06-2015-0312
9. Paschou, T., Rapaccini, M., Adrodegari, F., Saccani, N.: Digital servitization in manufacturing: a systematic literature review and research agenda. Ind. Mark. Manage. **89**(February), 278–292 (2020). https://doi.org/10.1016/j.indmarman.2020.02.012
10. Koskinen, K.U.: Project-based companies as learning organisations: systems theory perspective. Int. J. Project Organ. Manage. **3**(1), 91–106 (2011). https://doi.org/10.1504/IJPOM.2011.038866
11. Moretto, A., Patrucco, A.S., Walker, H., Ronchi, S.: Procurement organisation in project-based setting: a multiple case study of engineer-to-order companies. Prod. Plann. Control, 1–16 (2020). https://doi.org/10.1080/09537287.2020.1837938
12. Kujala, S., Kujala, J., Turkulainen, V., Artto, K., Aaltonen, P., Wikström, K.: Factors influencing the choice of solution-specific business models. Int. J. Project Manage. **29**(8), 960–970 (2011). https://doi.org/10.1016/j.ijproman.2011.01.009
13. Raja, J.Z., Chakkol, M., Johnson, M., Beltagui, A.: Organizing for servitization: examining front- and back-end design configurations. Int. J. Oper. Prod. Manage. **38**(1), 249–271 (2018). https://doi.org/10.1108/IJOPM-03-2016-0139
14. Grant, M.J., Booth, A.: A typology of reviews: an analysis of 14 review types and associated methodologies. Health Inf. Libr. J. **26**(2), 91–108 (2009). https://doi.org/10.1111/j.1471-1842.2009.00848.x
15. Grant, R.M.: Contemporary Strategy Analysis. Wiley, Chichester (2010)
16. Kujala, S., Artto, K., Aaltonen, P., Turkulainen, V.: Business models in project-based firms - towards a typology of solution-specific business models. Int. J. Project Manage. **28**(2), 96–106 (2010). https://doi.org/10.1016/j.ijproman.2009.08.008
17. Mourtzis, D., Boli, N., Fotia, S.: Knowledge-based estimation of maintenance time for complex engineered-to-order products based on KPIs monitoring: a PSS approach. Procedia CIRP **63**, 236–241 (2017). https://doi.org/10.1016/j.procir.2017.03.317
18. Ståhle, M., Ahola, T., Martinsuo, M.: Cross-functional integration for managing customer information flows in a project-based firm. Int. J. Project Manage. **37**(1), 145–160 (2019). https://doi.org/10.1016/j.ijproman.2018.11.002
19. Adrodegari, F., Alghisi, A., Bacchetti, A.: Analysis of servitization in engineering-to-order manufacturing companies: an empirical research. In: Proceedings of the Summer School Francesco Turco, 11–13 September, pp. 127–132 (2013)
20. Mourtzis, D., Angelopoulos, J., Boli, N.: Maintenance assistance application of Engineering to Order manufacturing equipment: a Product Service System (PSS) approach. IFAC-PapersOnLine **51**(11), 217–222 (2018). https://doi.org/10.1016/j.ifacol.2018.08.263
21. Ivory, C.J., Alderman, N.: Who is the customer? Maintaining a customer orientation in long-term service-focused projects. Int. J. Technol. Manage. **48**(2), 140–152 (2009)
22. Artto, K., Wikström, K., Hellström, M., Kujala, J.: Impact of services on project business. Int. J. Project Manage. **26**(5), 497–508 (2008). https://doi.org/10.1016/j.ijproman.2008.05.010
23. Pero, M., Stößlein, M., Cigolini, R.: Linking product modularity to supply chain integration in the construction and shipbuilding industries. Int. J. Prod. Econ. **170**, 602–615 (2015). https://doi.org/10.1016/j.ijpe.2015.05.011
24. Porter, M.E.: Competitive Strategy: Techniques for Analyzing Industries and Competitors. Free Press, New York (1980)